Making sense (and cents) of GPS Location, Location, Location

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Introduction

Global Positioning System (GPS) technology is ubiquitous. Surveyors have been using GPS for years to precisely locate marks on the surface of the earth. Most people are acquainted with non-survey level GPS technology as used in “smart bombs”, as a navigational aid in their vehicles (guide us to an Italian restaurant in an unfamiliar city), or in wayfinding (keep a log of our hike so that we can find our way back). You can even attach a GPS device to your child or pet to not loose either.

But how is WSDOT making use of this technology beyond an instrument for survey? WSDOT has been using this technology in unique and beneficial ways for some time and is realizing significant cost savings in many areas. Be assured that the use of this spatial technology will increase rapidly as equipment costs plummet and it’s ease of use and efficiency becomes readily apparent throughout the Department.

We present a two-part article on the non-survey (or inventory-grade) uses and benefits of GPS. In the first article, we present some groundwork by providing a very cursory explanation of GPS. We’ll focus some of the unique circumstances of trying to maximize its utility within the Department. Unfortunately, using an off-the-shelf, inventory-grade GPS receiver has limitations. You’ll see why. We’re here to explain what we are doing to maximize its benefits for transportation applications.

In the subsequent article we will review several case studies of actual GPS technology applications in practice within the Department and present the cost savings that are realized.

The Utility of GPS at WSDOT

The most common use of GPS for transportation is navigation. GPS applications for turn-by-turn driving instructions and optimized routing will soon be commonplace in vehicles. It can serve as the backbone technology for fleet management, optimized routing and logistics. It can guide equipment such as snowplows and graders to follow an accurate and precise course.

But GPS technology can revolutionize the efficiency of field data collection and management when compared with the traditional methods. Not only does GPS minimize the data collection effort in the field, the location from this equipment is the most reliable and accurate available. Manual recording (writing down a location and then verifying a location), takes more time and cost more money.

GPS techniques can be used to inventory the locations of roadside asset items such as signs, guardrails, pavement conditions, trees, utility devices, drainage systems, bridges, traffic devices, light poles, etc. It can accurately record the location of maintenance procedures such a mowing, spraying, or striping.

So at WSDOT, GPS is an indispensable navigation tool, and is quickly becoming the most cost-effective solution for tracking and managing assets along the road. Here's how it works.

The Very Basics of GPS

The Global Position System is a satellite-based radio navigation system developed by the Department of Defense for both military and civilian use. Twenty-four satellites circle 24,000 miles above the earth in six orbital planes. The orbital motion of each satellite is monitored by ground station so that their exact position is always known. Each satellite broadcasts a radio frequency signal. A GPS receiver on the ground determines when a timed signal left the satellite and when it arrived at the receiver. The GPS receiver measures the time required for the signal to travel from the satellite to the receiver. Then using sophisticated calculations, the signal travel time is converted to distance. The receiver triangulates the distance of three or more satellites and determines its position and altitude on the ground.

Sounds simple enough, but the simultaneous calculations are quite complicated to determine the receiver's position.   Further, the whole process is riddled with errors. These errors are in the form of imprecise signal timing, atmospheric distractions (clouds, particles), obstructions on the ground (trees, passing trucks), and limitations of the receiver. Fortunately, by using various filters, statistics, and a technique called *differential correction*, many of these errors are minimized. Depending on the amount of error correction, duration of signal input, quality of receivers, and a host of other factors, one can expect a positional accuracy of anywhere from a single decimeter to 100 meters. For our purposes (general navigation and inventory), it is necessary to obtain accuracy of 1-2 meters (3-6 feet). There is another catch, however.

The Language of GPS and the Language of WSDOT

Remembering back from your middle school lessons in Geography, recall that a location on the earth's surface can be expressed as latitude and longitude. Latitude is the angular distance north or south of the Equator, and longitude is the distance from the Prime Meridian. Thus location is expressed as 47.5836, -127.3948. For use at WSDOT, there are two problems with this technique.

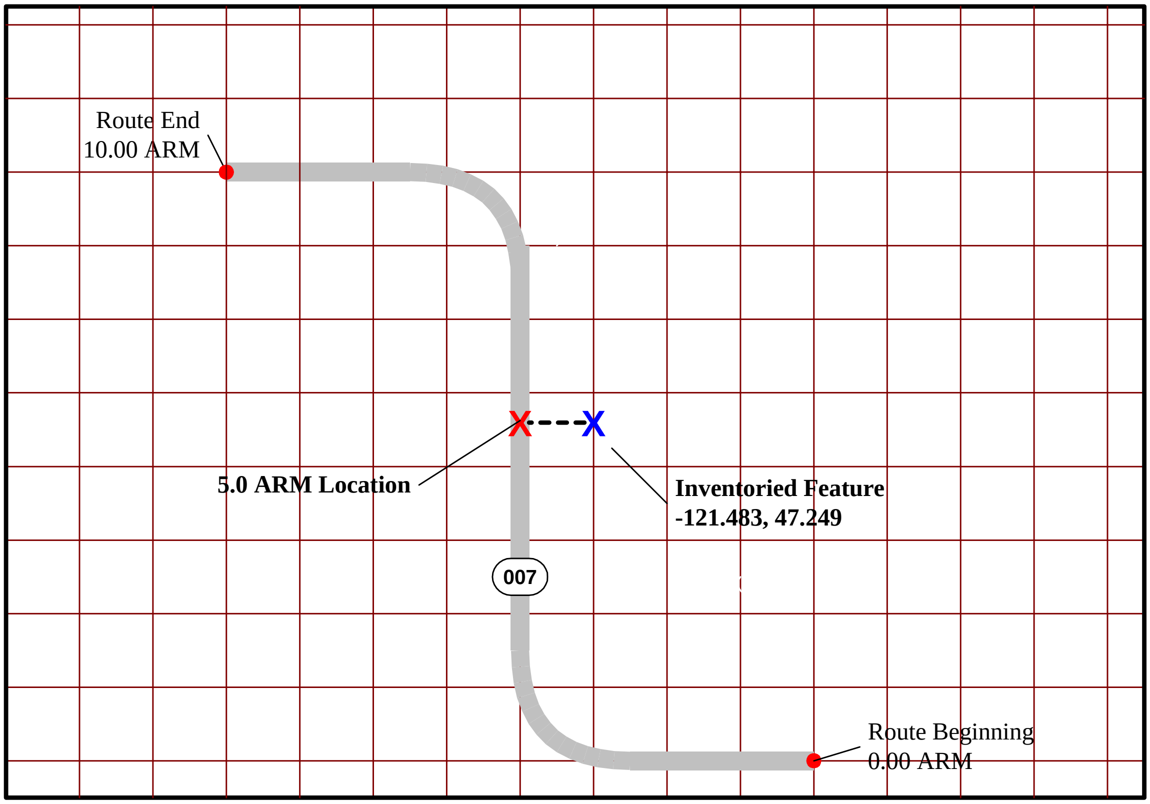
First, even for the most experienced cartographers, the spherical language of latitude and longitude is difficult to interpret. The location appears as a jumble of numbers with not much reference to everyday experiences. Second, the location language used throughout most of the Department is a linear expression – the State Route Milepost (SRPMP). SRMP is the distance of a route form it's beginning. The location of a bridge, for example, is said to be at milepost 139.5, or the exit ramp is at milepost 25. This Linear Referencing System (LRS) is much more intuitive when operating in a world or roads and highways.

So how do we make spatial sense in term of a LRS out of latitude and longitude from the GPS equipment? We're doing it with a computer technology using some very detailed maps and process called "map matching". Here's how it works.

Map Matching Explained

Map Matching is a function that snaps a point from a Cartesian coordinate system to the nearest location on a line. In the example below, the location of a feature (the "X"), such as a culvert, has been collected using GPS, and it's location is identified in terms of longitude and latitude. The point's location is placed on an electronic map that uses longitude and latitude as a referencing system (the grid lines). The road on the map is thus in the same coordinate structure as the inventoried feature. But it also uses a Linear Referencing System, or mileposts. So a position on the road can be described in terms of longitude, latitude and milepost values.

In the example below, the culvert's original GPS location was described as -121.482, 47.249, but the map matching process snapped the point to the nearest spot on the road. It determined the linear location to be at milepost 5 along the route. This is a similar process that goes on in all dashboard navigation systems to place the vehicle's location on the map, but we've modified it to be more WSDOT-specific.



Fine-Tuning the Road on the Map:

This road centerline map has been commonly referred to as the "smart road layer" in the Department's Geographic Information System (GIS). It is easy to see that positioning of features in terms of mileposts is constrained by the depiction of the road network. The more accurate the electronic map of the road, the more precisely the GPS position will be reconciled to a milepost.

At WSDOT there are currently two scales of centerline representations - the 500K (small scale) and the 24K (medium scale). Both of these representations are constructed by manually digitizing the road network from paper maps. This process is laborious and it's accuracy is limited to that of the published map (200ft. and 40 ft.) and by additional miscues when manually constructing this map.

Currently, a new process for depicting road centerlines on a map is underway that utilizes GPS and inertial guidance technology. The process consists of GPS equipment and inertial technologies installed on a van to collect points. Once the points have been collected, custom WSDOT software assembles the points into a new, highly accurate electronic road centerline. This project will accurately locate the entire state highway system using this mobile GPS technology and will achieve the level of accuracy similar to that derived from inventory-grade GPS devices (+/- 5 ft).